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United States Patent [19]
Sandhu et al.

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[45] **Date of Patent:** ***Nov. 30, 1999**

- [54] **IC MECHANICAL PLANARIZATION PROCESS INCORPORATING TWO SLURRY COMPOSITIONS FOR FASTER MATERIAL REMOVAL TIMES**
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- [73] Assignee: **Micron Technology Inc.**, Boise, Id.
- [*] Notice: This patent is subject to a terminal disclaimer.
- [21] Appl. No.: **08/992,399**
- [22] Filed: **Dec. 17, 1997**

Related U.S. Application Data

- [63] Continuation of application No. 08/692,903, Jul. 30, 1996, abandoned, which is a continuation of application No. 08/493,205, Jun. 20, 1995, Pat. No. 5,540,810, which is a continuation of application No. 08/109,848, Aug. 20, 1993, abandoned, which is a continuation of application No. 07/989,243, Dec. 11, 1992, abandoned.
- [51] **Int. Cl.⁶** **H01L 21/304**
- [52] **U.S. Cl.** **438/692; 438/633; 216/88**
- [58] **Field of Search** **438/692, 693, 438/633; 216/88, 89**

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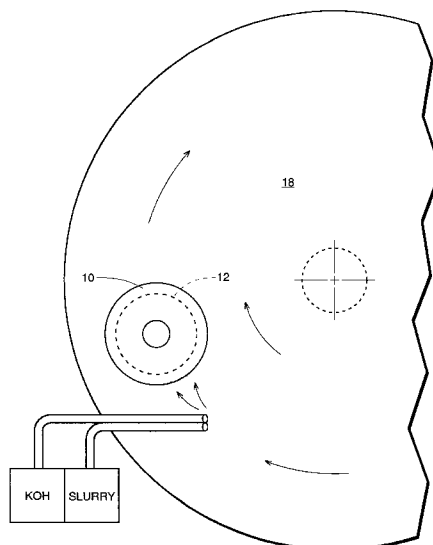
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Attorney, Agent, or Firm—Walter D. Fields

[57] **ABSTRACT**

The present invention relates to integrated circuits (ICs) fabrication. Particularly, there is a cmp process which incorporates small quantities of two chemicals. The first chemical is the standard slurry mixtures, like water, aluminum-oxide and hydrogen-peroxide mixed into a slurry. The second chemical is a strong base chemical, like KOH, or potassium hydroxide. Moreover, the cmp process utilizes a system of closely regulating the timing of the two chemical process. Specifically, during a first time period, both chemicals are applied; thus increasing speed of the chemical removal of tungsten material. During a second time period, the KOH is removed, thus slowing down the chemical action and importantly achieving a greater degree of planarization than is capable by the two chemical first time period.

24 Claims, 4 Drawing Sheets



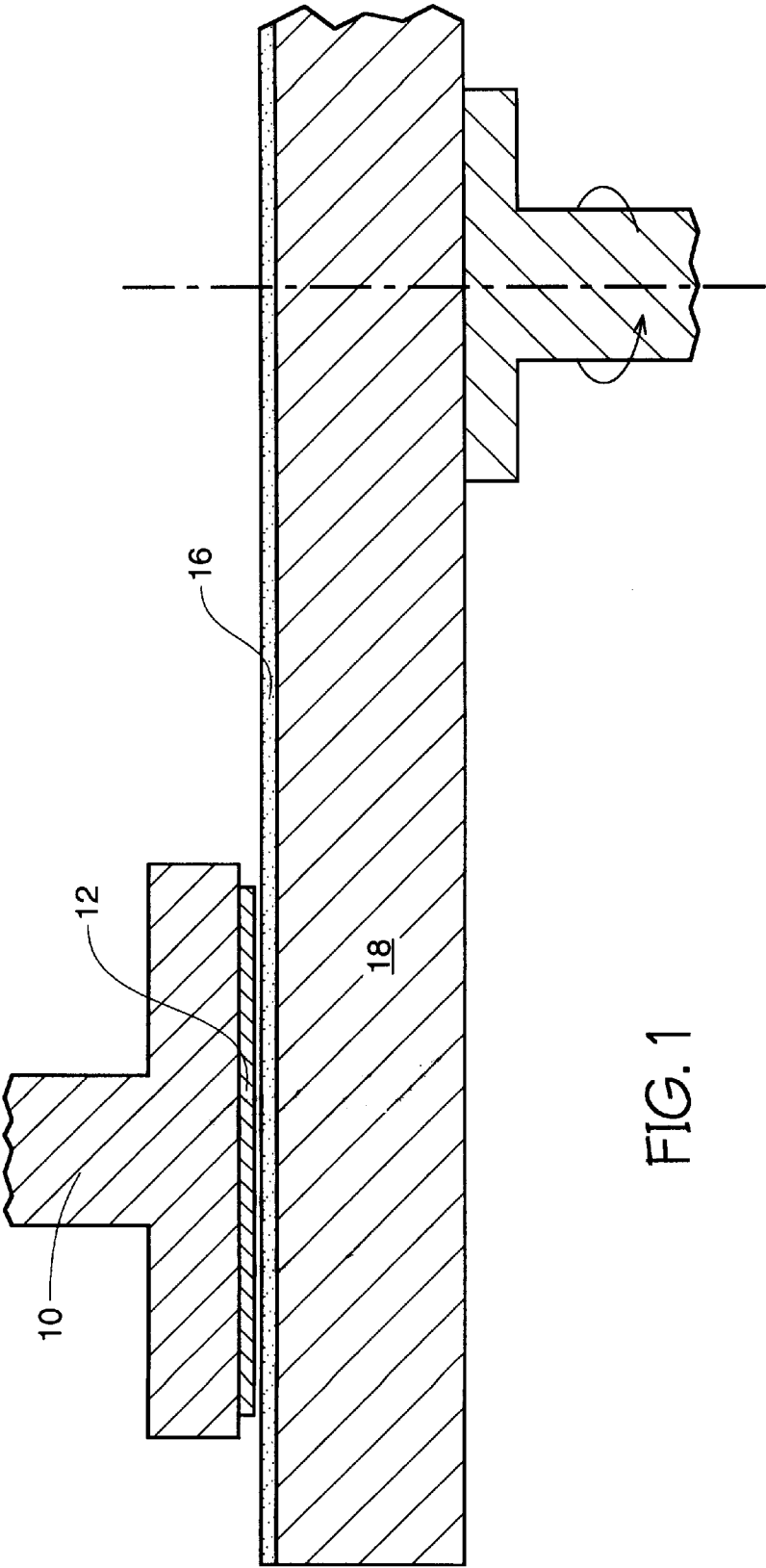


FIG. 1

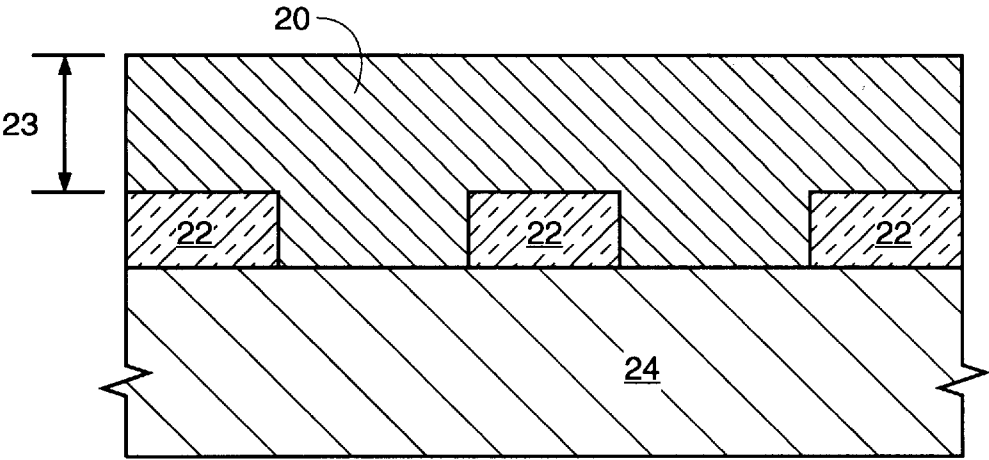


FIG. 2

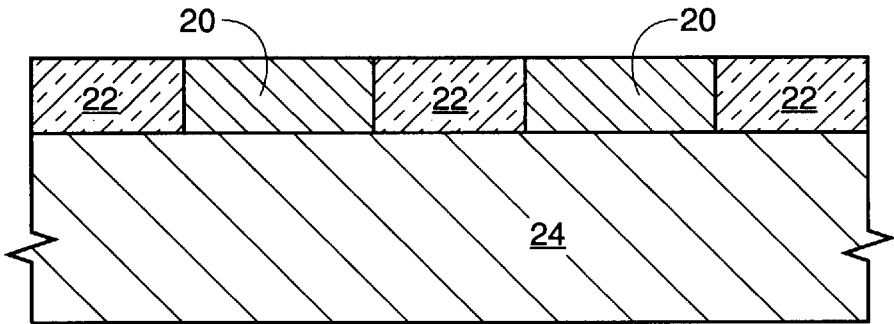


FIG. 3

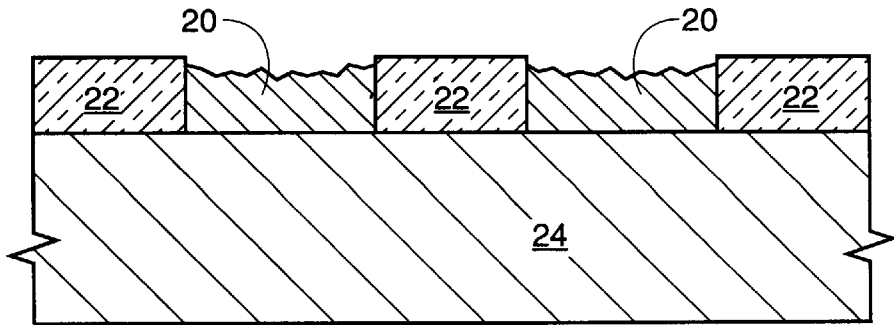


FIG. 4

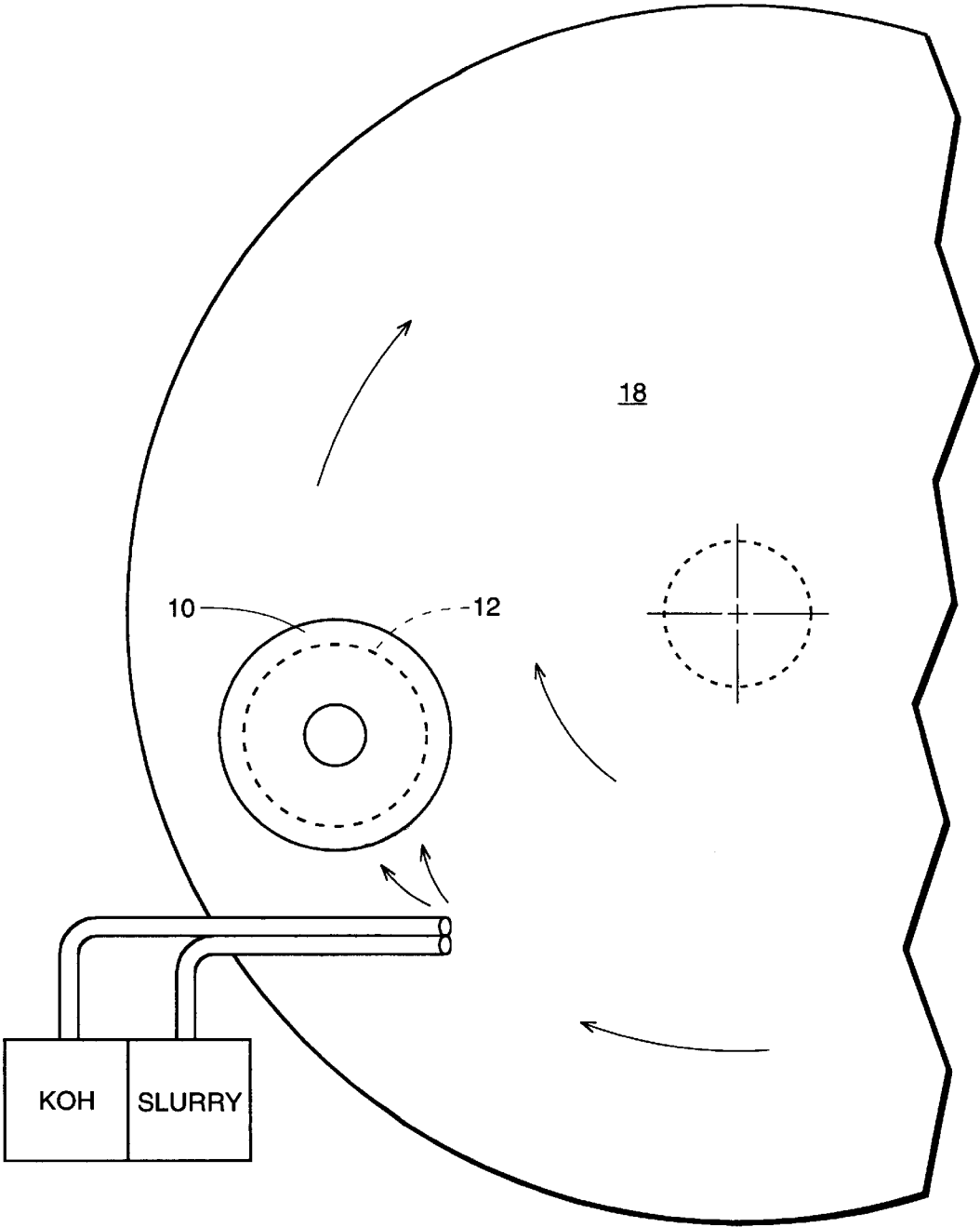


FIG. 5

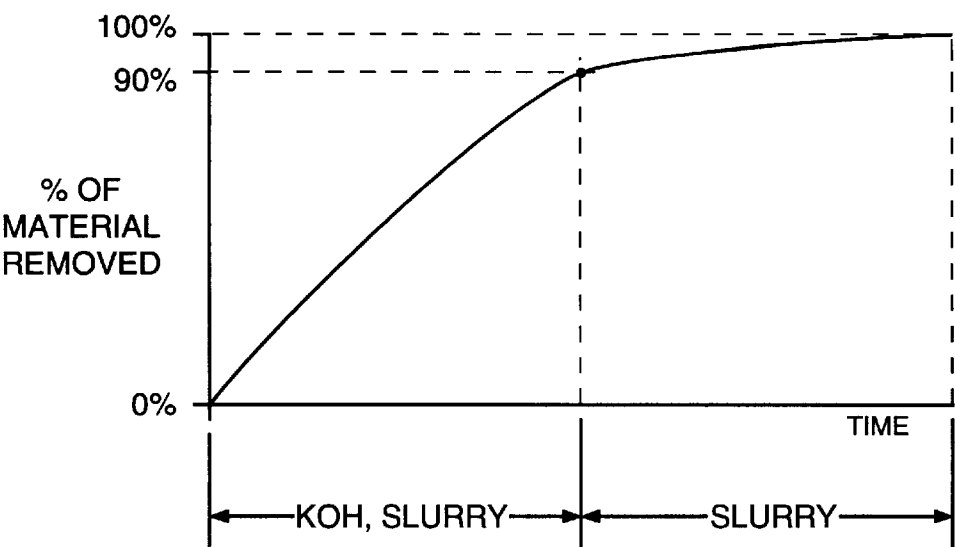


FIG. 6

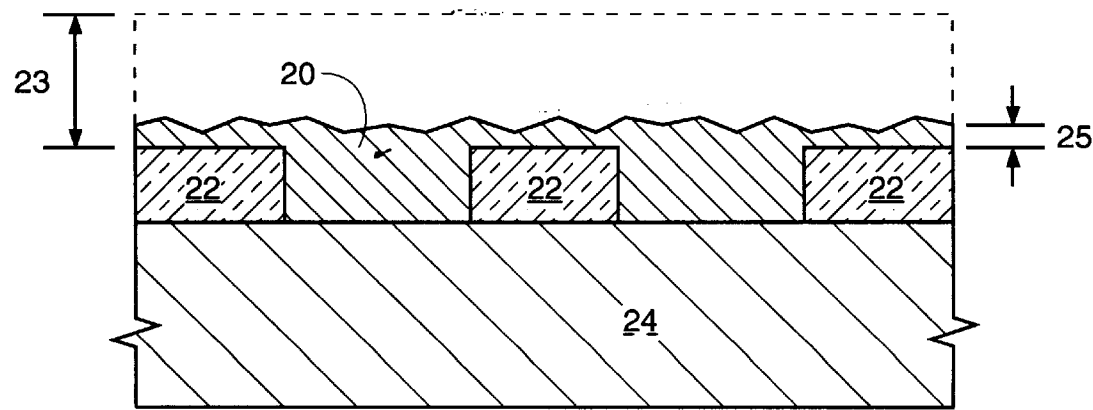


FIG. 7

IC MECHANICAL PLANARIZATION PROCESS INCORPORATING TWO SLURRY COMPOSITIONS FOR FASTER MATERIAL REMOVAL TIMES

CROSS-REFERENCES TO RELATED OR COPENDING APPLICATIONS

This is a continuation of application Ser. No. 08/692,903, filed Jul. 30, 1996, now abandoned which is a continuation of application Ser. No. 08/493,205, filed Jun. 20, 1995, now U.S. Pat. No. 5,540,810 issued Jul. 30, 1996, which is a continuation of application Ser. No. 08/109,848, filed Aug. 20, 1993, now abandoned, which is a continuation of application Ser. No. 07/989,243, filed Dec. 11, 1992, now abandoned.

U.S. patent app. Ser. No. 07/817,167, filed Jan. 6, 1992, now U.S. Pat. No. 5,270,587 is an application filed by the same assignee. U.S. patent app. Ser. No. 996,985, filed Dec. 23, 1992, now U.S. Pat. No. 5,300,155 entitled an IC chemical mechanical planarization process incorporating slurry temperature control, is an application filed by the same assignee.

FIELD OF THE INVENTION

The present invention relates to integrated circuits (ICs) fabrication. Particularly, there is a chemical mechanical planarization (CMP) process incorporating the controlled timed release of two chemical mixtures. Uniquely, the CMP process speeds dramatically increase when applying the two stage chemical process.

BACKGROUND OF THE INVENTION

Historically, chemical mechanical planarization, also known as "CMP," has been developed for many uses in the semiconductor industry; like removing a thin top layer of material from a semiconductor wafer.

A representative CMP machine, as illustrated in FIG. 1, comprises: a wafer carrier **10** holding a semiconductor wafer **12** which is pressed against a course polishing pad **16** mounted on a platen or holder **18** which rotates about its axis. Not shown in this figure, is the chemical slurry which is applied to the pad **16** for using chemical action to further aid in removing material from the surface of the semiconductor wafer **12**.

In operation, a CMP machine works like a sanding machine and acid bath combined. To mechanically remove wafer material, wafer **12** is positionally fixed and held against abrasive polishing pad **16** while platen or holder **18** rotates. The chemical slurry is used to chemically remove the wafer material.

FIG. 2 illustrates a representative cross section of a wafer **12** comprising: a tungsten material **20** having a top surface layer **23**, a few silicon-type material sections **22**, and a wafer base **24**.

FIG. 3 illustrates the desired resulting wafer design desired after removing the appropriate amount of top layer material **23**; thus, leaving a smooth and plainer top surface.

Problems

A major problem with current CMP processes is that FIG. 3 is a goal that is achievable only by a long process time; usually requiring seven or more minutes. As illustrated in FIG. 4, it is shown that material **20** has not achieved a level surface that is even with the silicon-type material sections

22. This situation occurs because the chemical removal process usually continues to remove the tungsten even after the mechanical material removal process has ceased. It has been difficult to control the chemical removal process. The option of discarding the chemical process is not possible, it being the fastest removal process. Therefore, complex timing schemes have been developed for removing the wafers before the chemical process removes too much tungsten.

It is noted that the above described problem, as well as other problems, are solved through the subject invention and will become more apparent, to one skilled in the art, from the detailed description of the subject invention.

SUMMARY OF THE INVENTION

One skilled in the art will appreciate the advantage of the subject CMP process. Specifically, there is a CMP process which incorporates small quantities of two chemicals. The first chemical is the standard slurry mixtures, like water and aluminum trioxide mixed into a slurry. The second chemical is a strong base chemical, like KOH, or potassium hydroxide. Moreover, the CMP process utilizes a system of closely regulating the timing of the two chemical process. Specifically, during a first time period, both chemicals are applied; thus increasing speed of the chemical removal of tungsten material. During a second time period, the KOH is removed, thus slowing down the chemical action and importantly achieving a greater degree of planarization than is capable by the two chemical first time period.

Other features and objects of the present invention will become more clear from the following detailed description of the invention, taken in conjunction with the accompanying drawings and claims, or may be learned by the practice of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustration of a CMP machine.

FIG. 2 is a cross sectional view of a wafer before undergoing a CMP process.

FIG. 3 is a desired cross sectional view of a wafer after successful removal of the top tungsten layer.

FIG. 4 is a cross sectional view of a wafer after undergoing a typical CMP process.

FIG. 5 illustrates a top view and representation of the CMP process.

FIG. 6 illustrates the percentage of material removed over time given the first and second one minute time periods.

FIG. 7 illustrates a representative side view of a die on a wafer after undergoing the first time period of the proposed CMP process.

It is noted that the drawings of the invention are not to scale. The drawings are merely schematic representations, not intended to portray specific parameters of the invention. The drawings are intended to depict only typical embodiments of the invention, and are therefore not to be considered limiting of its scope. The invention will be described with additional specificity and detail through the use of the accompanying drawings. Additionally, like numbering in the drawings represent like elements within and between drawings.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENT

Incorporated Material

The following U.S. patents are herein incorporated by reference for pertinent and supporting information:

U.S. Pat. No. 4,992,135, is a method of etching back of tungsten layers on semiconductor wafers, and solution there-fore.

U.S. Pat. No. 4,811,522, is a counterbalanced polishing apparatus.

U.S. Pat. No. 4,193,226, is a polishing apparatus.

U.S. Pat. No. 3,841,031, is a process for polishing thin elements.

General Embodiment

The following discussions are in reference to both FIGS. 5, 6 and 7. FIG. 5 illustrates a top view and representation of the CMP process. Specifically, it is demonstrated that KOH and slurry mixtures are applied to the CMP process via separate application delivery mechanisms, like tanks, pumps, and tubes. The two delivery design is unique to the invention. If KOH were to be mixed with the slurry, in a relatively short time, the slurry will begin to titrate, or harden instead of remaining in a slurry mixture; thereby clogging the delivery mechanism. Thus it would be impos- sible to apply the combined mixture for any length of time. However, by separating the two chemicals, the separate application quantities and timing of those quantities can now be controlled.

FIG. 6 illustrates the percentage of material removed over time given the two chemical application time periods. One skilled in the art will recognize that approximately 90% of the top tungsten layer is removed during the first CMP process period. Uniquely, both chemicals are applied to the process, where KOH will perform the majority of the material removal. FIG. 7, illustrates that the planarization of the removed material is relatively rough, yet there remains a small portion 25 remaining to be removed.

Again, referring to FIG. 6. One skilled in the art will understand that the removal of the KOH from the second time period will significantly slow the chemical removal process. In contrast, it is understood that during the second time period, a major portion of the remainder of the material selected for removal is eliminated by mechanical action. Mechanical material removal processes are much slower than chemical; however, mechanical processes are more precise in controlling the quantity of material to be removed. Uniquely, by combining the slurry and mechanical material removal process, a smooth planarization as was illustrated in FIG. 3 is achievable at a significantly faster rate than prior methods.

Remarks about the Invention

It is noted, by using the basic KOH chemical for a short period of the CMP process, roughly 80 to 90% of the material can be removed in the first time period. Whereas, prior art methods would have taken roughly 6 times the amount of time to accomplish the same task. Moreover, by eliminating the KOH application for the second time period, there is only a 10 to 20% of the material remaining to be removed by the conventional CMP process to achieve the desired planarization quality. Thus, only 10 to 20% of the time is the new method working as slow as prior art methods.

It is additionally noted that during the first time period the majority of the material is removed by the chemical action from the two chemical mixtures. However, it should not be forgotten that a minority of the material, removed in this first time period, is removed by the mechanical action from the abrasive polishing pad 16.

Similarly, it is noted that during the second time period the majority of the material is removed by the mechanical action from the abrasive polishing pad 16. The minority of the material, removed in this second time period, is removed by the chemical action of the slurry chemical mixture. Mechanical material removal is slower, yet it is more precise for achieving a greater planarized surface than is achievable with the chemical action. This is one of the main reasons that a diluted slurry is used during the second period.

Variations in the Invention

There are several obvious variations to the broad invention and thus come within the scope of the present invention. Uniquely, this invention may work with any material (metals or dielectrics) to be removed via CMP processes; for example, Al, Cu, silicon dioxide, silicon nitride, etc. Additionally, any typical slurry chemical used in a CMP process will yield satisfactory results.

Another variation to the invention, and in reference to FIG. 6, is that the time taken for the first time period (having KOH) may be varied for several reasons. If the concentration of KOH is increased, then the overall time to remove a given amount of material will decrease. Similarly, if it is possible to remove more than 90% of the material with KOH then the overall time of the first period would increase. However, if it is not possible to accurately or finely control the quantity of the material to be removed then it may be advantageous to stop the removal process at about 80% before initiating the second time period of the CMP process. It is also noted that any combination of KOH concentrations and control of the removed material quantity will equally effect the timing between the first and second time periods. Therefore, the two time periods do not have to be equal. However, it is restated that not matter what the time periods are, the overall time for this new process will be much less than prior art processes not utilizing the KOH or equivalent chemicals.

Another variation is to have the two chemicals in the two tanks mixed before being applied to the surfaces of wafers. This could be done by joining the delivery tubes or by having an intermediate tank where the chemicals are then mixed

Similarly, it is noted that, although the invention describes the use of two timing periods with the use or non use of KOH distinguishing the two periods, it is obvious to vary the timing periods to be multiple periods. With multiple periods, varying amounts of KOH, or its equivalents, can be applied over the various periods. This could allow the use of several concentrations of KOH to regulate the varying rates of material removal and planarization achievable.

While the invention has been taught with specific reference to one embodiment, someone skilled in the art will recognize that changes can be made in form and detail without departing from the spirit and the scope of the invention. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

Although subheadings in the Detailed Description of the Illustrated Embodiment are used, these are merely provided for assisting the reader; wherein, the writer is free to enter any information under any heading/s.

What is claimed and desired to be secured by United States Patent is:

1. A method of planarizing a substrate, comprising:
providing a substrate having an exposed layer over an underlying structure.
pressing said substrate against a chemical mechanical planarization (CMP) polishing surface;
planarizing said substrate using the CMP polishing surface and a CMP slurry and removing a portion of said exposed layer at a first planarization rate;
after removing a portion of said exposed layer, changing a pH of the CMP slurry; and
planarizing said substrate using the CMP polishing surface and the pH adjusted CMP slurry and removing a further portion of said exposed layer at a second planarization rate.
2. A method according to claim 1, wherein said step of changing the pH comprises altering a flow of pH adjusting solution being supplied to said polishing surface.
3. A method according to claim 2, wherein said pH adjusting solution comprises a basic solution having a pH less than 7.0 and said altering comprises decreasing said flow.
4. A method according to claim 3, wherein said decreasing comprises stopping the flow of said basic solution.
5. A method according to claim 1, wherein at least 80% of said exposed layer is removed before starting said step of changing the pH of the CMP slurry.
6. A method of planarizing a semiconductor substrate, comprising:
providing a semiconductor substrate, said semiconductor substrate having at least one layer of material to be planarized;
chemical mechanical planarizing (CMP) said at least one layer of said semiconductor substrate using a CMP slurry solution; and
modifying a pH of the CMP slurry solution during said chemical mechanical planarizing of said semiconductor substrate and affecting a planarization rate thereof.
7. A method according to claim 6, further comprising:
supplying a CMP solution and supplying a pH affective solution to form said CMP slurry solution;
wherein said modifying comprises changing a flow ratio of the pH affective solution relative the CMP slurry solution.
8. A method according to claim 7, wherein said pH affective solution comprises a basic pH.
9. A method according to claim 7, wherein said modifying comprises reducing the flow of the pH affective solution.
10. A method according to claim 7, wherein said modifying comprises terminating a flow of the pH affective solution.
11. A method according to claim 6, further comprising modifying the pH of said CMP slurry solution after remov-

ing a majority of said at least one layer of material during said chemical mechanical planarizing.

12. A method according to claim 11, wherein said at least one layer comprises an electrically conductive material.
13. A method according to claim 11, wherein said at least one layer comprises tungsten.
14. A method of planarizing a wafer, comprising steps of:
providing a wafer having a layer of first material over a second layer;
supplying a chemical mechanical planarization solution and a pH adjusting solution as a CMP slurry mixture; chemical mechanical planarizing said wafer using said CMP slurry mixture; and
after removing a first portion of said layer of first material, altering a flow ratio of said pH adjusting solution relative said chemical mechanical planarization solution during said planarizing of said wafer sufficiently to change the rate of planarization.
15. A method according to claim 14, wherein said pH adjusting solution comprises a basic pH.
16. A method of planarizing a layered semiconductor substrate, comprising steps of:
providing a substrate with at least one layer;
planarizing said at least one layer by chemical mechanical planarization using a CMP slurry and removing a first portion of said one layer at a first planarization rate; and
adjusting a pH of said CMP slurry to provide a second planarization rate and removing a second portion of said one layer, said second planarization rate resulting in removal of material of said one layer more slowly than said first planarization rate.
17. A method according to claim 16, further comprising:
supplying a first chemical solution and a second chemical solution, the first chemical solution and the second chemical solution providing said CMP slurry;
wherein said step of adjusting the pH comprises changing a supply flow of said first chemical solution.
18. A method according to claim 17, wherein said first chemical solution comprises a basic pH.
19. A method according to claim 17, wherein said changing comprises stopping the supply flow of said first chemical solution.
20. A method according to claim 16, wherein said first portion comprises at least 80% of said one layer.
21. A method according to claim 20, wherein said one layer comprises an electrically conductive material.
22. A method according to claim 16, wherein said one layer comprises tungsten.
23. A method according to claim 14, wherein said first portion comprises at least 50% of said layer of first material.
24. A method according to claim 14, wherein said step of altering the flow ratio of said pH adjusting solution comprises stopping the flow of said pH adjusting solution.

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

Page 1 of 1

PATENT NO. : 5,994,224
DATED : November 30, 1999
INVENTOR(S) : Gurtej S. Sandhu; Richard L. Elliott; Trung T. Doan; Jody D. Larsen

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the claims, correct claim 6 as follows:

6. A method of planarizing a semiconductor substrate, comprising:
- providing a semiconductor substrate, said semiconductor substrate having at least one layer of material to be planarized;
- chemical mechanical planarizing (CMP) said at least one layer of said semiconductor substrate using a CMP slurry solution; and
- modifying a pH of the [CUT] CMP slurry solution during said chemical mechanical planarizing of said semiconductor substrate and affecting a planarization rate thereof.

Signed and Sealed this

Tenth Day of July, 2001

Nicholas P. Godici

Attest:

Attesting Officer

NICHOLAS P. GODICI
Acting Director of the United States Patent and Trademark Office